Indian Journal of Spatial Science
Spring Issue: 2024:15(1) pp.1 - 10

Indian Journal of Spatial Science

Peer Reviewed / Refereed Journal

EISSN: 2249 - 4316 Homepage: www.indiansss.org ISSN: 2249 - 3921

An Appraisal of the Historic Urban Hydraulic Systems of Bijapur, Karnataka, India

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Article Info

Article History
Received on:
26 September, 2023
Accepted in *Revised Form* on:
15 February, 2024
Available *Online* **on and from:**
21 March, 2024

Keywords
Khair-e-Jari,
Karez,
Qanat,
Surang-Bawdi,
Ganj,
Talab,
Sarovar.

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Abstract

The city of Bijapur is located in the dry Deccan region of India. Yet, it ensured a sustainable water supply to its citizens for agricultural or domestic use during the 14th to 18th centuries under the Bahmani and Adil-Shahi dynasties. Two unique urban water systems, the Khair-e-Jari, and Muhammed Nada, accompanied by several cisterns, made it possible to populate and develop a city in the semi-arid region of India. Watershed management techniques were applied to ensure the sustainability of these water systems. Though in ruins, it provides water for irrigation and domestic use even today. Extensive ground surveys were conducted to record every segment using a mobile-based mapping application and handheld navigation device. Satellite data, topographical maps, historical maps, and literature reviews aided in linking up all segments to prepare the first complete map of the Khair-e-Jari and Muhammed Nada water systems. Bijapur, a heritage city of Karnataka State, has undergone unplanned organic urban growth coupled with a lack of awareness, understanding, conservation practices, and appropriate implementation of existing policies. This has resulted in an unsustainable geophysical alteration of the fragile hydraulic landscape affecting these unique water systems. The objective of this article is to bring to light the urban water heritage of Bijapur through mapping and unraveling its utility, construction techniques, and the profound knowledge of watershed management that underpinned their success while aiming to ignite a flame of awareness towards the conservation of this invaluable water heritage. This paper delves into the intricate details of the historic urban water systems of Bijapur. It discusses the challenges in conserving them as national heritage, emphasizing the need for urgent action to ensure their preservation for future generations.

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Introduction

There is hardly any city in India which receives a 24-hour drinking water supply when providing clean drinking water is one of the primary priorities and obligatory functions of a city administration. One such successful attempt was made about 530 years ago at Bijapur city (Fig.1) by the Adil Shahi kings (1490-1686) successfully through three means: the Khair-e-Jari or *Surang-Bhawi* (tunnel-well in Kannada) (Nazim, 1836), Ganj-Pipeline network (network of water towers and terracotta pipelines) and Public Bawdi's (cisterns). The spatial arrangement was such that the rich and the poor had easy access to potable water. The defence perspective was probably overlooked, considering water availability while selecting the site for Bijapur City; this was totally against the convention of Medieval period dynasties in India (Sohoni, 2017). The city sits in a sink with a highly dissected and undulating topography of the Deccan Plateau. The plateau soils are shallow along the slopes and uplands, while the valleys with thicker layers are extensively cultivated. Below the fine clayey soil

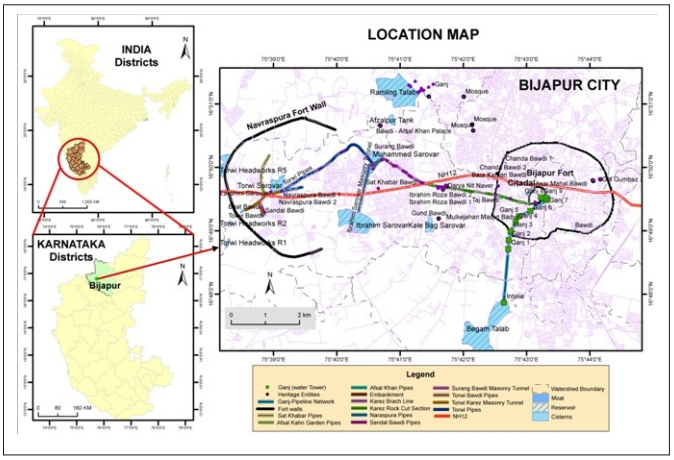


Fig.1: Location Map of Bijapur City

On the surface is the weathered basaltic layer (vesicular basalt), and further below the harder Deccan Trap as bedrock. The vesicular

basalt layer forms a fairly good aquifer. Tree crops like tamarind and mangoes dominated the landscape along the slopes and valleys and are now giving way to unprecedented unplanned urbanization.

Bijapur receives an annual rainfall of 700mm or less on the leeward side of the Western Ghats. Despite the general barrenness of the landscape and low rainfall, groundwater resources at Bijapur have been good. The surface streams are non-perennial, and drought is becoming a common phenomenon annually. Most villages are located along with surface water sources, and open wells are the direct source of groundwater during challenging times. Several recharging structures referred to as Talab's and Sarovar's (reservoirs) support the vesicular basaltic aquifer. Surface and groundwater resources were developed ingeniously, providing 24x7 potable water to its citizens. All three urban water supply schemes were developed and served the fort city and the immediate surroundings. The *Khair-e-Jari* is the local name for the *Karez* or *Qanat* water systems in Bijapur, but the procedure is much more complex than seen anywhere else. *Muhammed Nada* is a unique network of Ganj (water towers) and terracotta pipelines from Begam Talab, and Bawdi's are the large cisterns that dot the city area.

Until recently, Bijapur's intricate medieval urban water systems remained in mystery. Their precise function and the sophisticated watershed management practices employed during medieval times in the Deccan region were shrouded in obscurity. This study aimed to illuminate this enigma by meticulously mapping and analyzing these ancient networks. The secrets hidden beneath the surface have been uncovered through meticulous ground surveys and cutting-edge technologies like mobile mapping applications and satellite imagery. The intricate network of tunnels, terracotta pipelines, and reservoirs sheds light on the ingenious methods of construction employed centuries ago. This groundbreaking research provides a detailed understanding of Bijapur's water infrastructure and offers valuable insights into the advanced water management techniques practised during medieval times. By piecing together the puzzle of these ancient systems, we gain a deeper appreciation for the ingenuity and foresight of past generations.

Furthermore, this study has paved the way for further research and conservation efforts. The precise map and detailed analysis of construction methods provide a crucial foundation for future projects to safeguard this invaluable heritage. By ensuring the preservation and ongoing study of these remarkable systems, we can learn from the wisdom of the past and apply it to create a more sustainable future. This research highlights the importance of preserving and studying historical water systems. By understanding the intricate details of these systems, we can gain valuable insights into the ingenuity and resourcefulness of past civilizations. This knowledge can then be applied to address contemporary water challenges and develop more sustainable solutions for future generations.

Materials and Methods

The Karez systems in India are an enigma to the rest of the world. Research on Karez in India is limited to historical literature reviews or architectural studies. This work aimed to prepare a detailed map and carry out a geographical analysis. Extensive field surveys were carried out to map and record all entities connected with the historic water system. The entities included air vents of the Karez system, remains of the terracotta pipeline network, embankments and reservoirs, water control systems, pressure valves, cisterns, tanks, open wells, Ganj (water towers) etc. Most of these entities are in dilapidated condition, with visible remains on the surface, thus making it easier to record the geocoordinates. The air vents were inspected physically by climbing down into the Karez Gallery. The accumulated debris does pose a hindrance to movement inside the Karez gallery; some sections are completely inaccessible due to this.

Mobile mapping application SoftWel Maps (SW Maps) was used to record the entity geocoordinates. A handheld navigation system device was also used to capture the geocoordinates. These locations were saved as point feature shapefiles, transferred to the GIS platform, and processed to prepare the historic urban water system map for Bijapur. ArcGIS 10.5.1 GIS software was used to plot the mapped locations to their geo coordinates on a georeferenced Survey of India topographical map (1:25000). Further, ASTER Satellite data (acquired from the USGS Earth Explorer platform) with 30m resolution DEM was used to extract the elevation zones, watershed boundaries and stream network, which was further refined using Survey of India Topographical maps and inputs from ground investigations. Overlay spatial analysis was performed on ArcGIS 10.5.1 GIS software to superimpose the historic urban water systems on elevation zones, watershed boundaries and stream networks. Available literature was studied in detail to establish linkages and associations with the cultural landscape of Bijapur during medieval times.

A Brief History of Bijapur

The foundations for the city of Bijapur were laid by Chalukyas of Kalyani during the 10th Century ACE. They were called Vijayapura, which was later passed on to the hands of Yadavas in the 11th Century ACE and further to the Bahmani in 1347 (Nazim, 1836; Sathyan, 1966). The city prospered under the governorship of Yusuf entitled Adil Khan, a Turk who had entered the service of Bahmani during the early part of 15th Century ACE (Sherwani, 1985). Later, as the Bahmani power started fading at Bidar, Yusuf Adil Khan's allegiance to Bahmani also started waning. Soon enough, the Bahmani state disintegrated into five Deccan kingdoms: Berar, Bidar, Bijapur, Golconda, and Ahmednagar. Around 1490, Yusuf Adil Khan assumed the title of 'Shah' declared sovereignty over Bijapur and led a successful campaign against its southern neighbour Vijayanagara (Gazetteer-Bijapur, 1884). Since then, both have been at war to establish control over the fertile plains of the river Krishna. In 1565, a major battle was fought between Bijapur and Vijayanagara at Talikot, which destroyed the Vijayanagara Kingdom. The kings of Golconda and Ahmednagar supported Bijapur during the venture (Sherwani, 1985).

After Ali Adil Shah, a minor succeeded Queen Chand Bibi as regent. In the meantime, the Mughal Emperor Shahjahan attacked Ahmednagar, and Bijapur aided Ahmednagar. But they had to concede defeat and return; Ahmednagar was taken over by the Mughals (Sherwani, 1985). On the other hand, the rise of Marathas under Shivaji also brewed problems for Bijapur. The Adil Shahi's power weakened, and by late 1685, the Mughals, under Aurangzeb's leadership, annexed all their territories (Gazetteer-Bijapur, 1884).

Though wars had kept the Adil Shahi kings busy, they contributed a lot to city development, which included the construction of an urban water supply system, a large mosque at Bijapur, etc. (Nazim, 1836; Cousens, 1889; Yazdani, 1944). Massive city walls were erected along with moats to protect the main city. A total of 96 bastions were constructed along the fortifications to defend the city. The fort has five major gates: Makka Gate to the West, Shahpur Gate to the North East, Bahmanhalli Gate to the North, Allahpur Gate to the East and Ittanhalli / Hitanalli Gate, which Aurangazeb renamed Fateh Darwaza (Gate) to the South East, all with bastions protecting them (Nazim, 1836). The citadel also has a separate moat and wall protection. Later, the city expansion was planned, and new fortifications were developed about 6 km west and named Navraspura (Cousens, 1889; Sathyan, 1966). A Straight arterial road connected the central city to Navraspura; Markets developed along this road. Even now, this road passes through the main commercial district of Bijapur. The relics of the Adil Shahi period dot the landscape of Bijapur. One among them is the historic urban water systems, which were the most notable among the citizen services of Bijapur.

Fig.2: A Wall painting at Torwi Lakshmi Temple depicting Ibrahim Adil Shah II as a hermit.

The Historic Urban Water System of Bijapur

The water-related infrastructure is inseparable from the cultural identity of Bijapur. This is indelibly linked to the emotional, social, political and cultural pride of the ruler and the people. Elaborate hydro-infrastructure construction was taken up by appointing Persian engineers under the supervision of royal court *Amirs* (nobles) (Mate, 1998). There are folklore and stories associated with such projects that make them immortal forever, though not physically. One such folk story is depicted in the painting on the walls of Torwi Lakshmi Temple, which describes Ibrahim Adil Shah II as a hermit who has convinced the goddess Ganga to bless his kingdom (Fig.2). The goddess obliges, but under one condition: Ibrahim will show the way and won't look back at Ganga. The doubtful Shah looked back, and Ganga disappeared, saying you can dig to find me.

The place of arrival of Ganga is considered to be the present headworks of Khair-e-Jari. This story depicts cultural harmony and rulers' integration of local beliefs and faiths, ensuring cooperation and allegiance to the kingdom. Being a drought-prone region, the significance of water supply was immense and the water provider becomes supreme. Bijapur is dotted with a variety of water structures. Some are ingenious works of that time.

The Bijapur's historic urban water system is a combination of Khair-e-Jari / Surang-Bhawi (tunnel-well in Kannada) (Govindankutty, 2016), terracotta / earthen pipeline network, Ganj (water towers), artificial reservoirs (using mud/stone embankments) and Bawdi's (Cisterns) **(**Fig.3**)**. This multi-source water management system was undertaken and completed during the reign of the Bahmani and Adil Shahi kings (Mate, 1998). It also showcases the deep understanding of engineers on rainfall patterns, local terrain, geology, slope and aquifer properties. The spatial arrangement of urban water supply systems reflects good planning and management of city services. These urban water systems also contributed to watering royal gardens and irrigating agricultural lands. A fourth system, which could not be traced entirely, starts from the Chalukya period reservoir and is called Ramling Talab (Nazim, 1836). A network of Ganj pipelines runs from here towards the city, but only a few exist today. Landscape modification and land-use change have erased them without a trace.

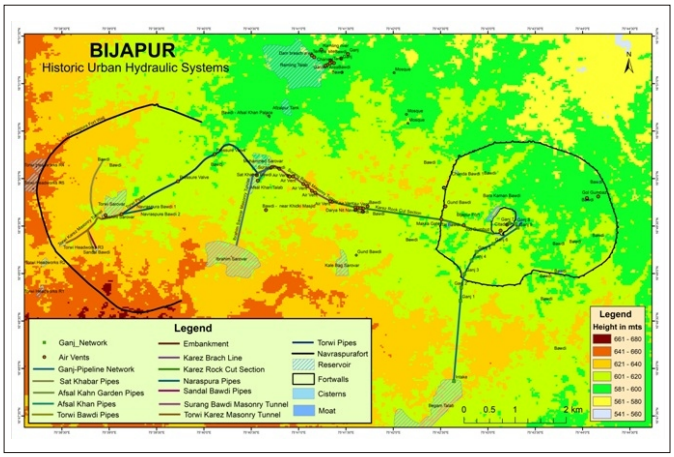


Fig.3: The Historic Urban Water Systems of Bijapur

It is interesting to note that the community of Bijapur city may have enjoyed an unhindered good drinking water supply through the summer months. Though not a household-level system, everyone in the community had access to public water fountains or cisterns. The palaces of kings, nobles, wealthy merchants, and other important citizens had household-level water pipeline connections. The physical setting of Bijapur city is at a lower elevation than the surroundings. Thus, gravity and natural slope ensured water flow to the citadel.

Bijapur is a city with a large number of palaces and gardens spread over undulating topography. Their spatial distribution, increasing urban population and higher water demand resulted in developing small, decentralized to large public water systems to suffice the needs. The best example of a small decentralized system is at Afsal Khan palace, while two large public systems are the Khair-e-Jari and Ganj-Pipeline network from Begam Talab. The cisterns are an example of a small community-level water system, some connected with Khair-e-Jari or the Ganj-Pipeline network. These were huge labour-intensive projects sanctioned by the rulers, supervised by nobles, and done by expert Persian engineers. The Khair-e-Jari was part of an expansion scheme from Bijapur to Navraspura and tapped the floodwaters of the Torwi stream.

The medieval cities in Deccan, namely Bidar, Aurangabad, Ahmednagar, Hukeri and Burhanpur (Govindankutty, 2018) have

remnants of such water systems, some functioning, others in ruins. People have moved on with new technologies aiding in reaching deeper into Earth to harness groundwater and fill their overhead tanks at the click of a button. The ever-expanding urban area, especially when it is organic and unplanned, is not mindful of such heritage structures, even for the sake of learning or as a live water museum showcasing the ingenious constructions of the period. The earliest work on such a great water system was initiated at Bidar during the early 15th Century (Govindankutty, 2013), which is a simple groundwater drawing Karez system similar to those in Iran. Still, the systems at Bijapur are a much-improved version with additional use of surface water and complex controlling mechanisms. Similarly, the Ganj-Pipeline network is also unique to Bijapur. In addition, is the network of cisterns so spatially arranged that every citizen had access to it. These three systems and their character-defining elements have been described in detail.

The Khair-e-Jari of Bijapur

The Khair-e-Jari is a unique water system brought to India by a ruling class with roots in the West and Central Asia region. Several Karez systems were constructed in India during medieval times, mainly in the Deccan region. *Karez*, Qanat, or Khair-e-Jari mean the same thing: an underground channel to carry water. Karez is a *gently sloping gravity tunnel connected to the surface by a series of shafts or vents nearly at equal intervals. It is constructed mainly below the water table in a variety of geology to harvest, transport and distribute water from the source to the point of use* (Beaumont, 1973; Mahdavi, 1992; Govindankutty, 2018) (Fig.4). *The Karez systems in India were almost an enigma until 2012. The detailed mapping of the Naubad Karez system by the author and simultaneously that of systems at Bijapur, Aurangabad, Ahmednagar and Buranpur led to renewed vigour in understanding them.*

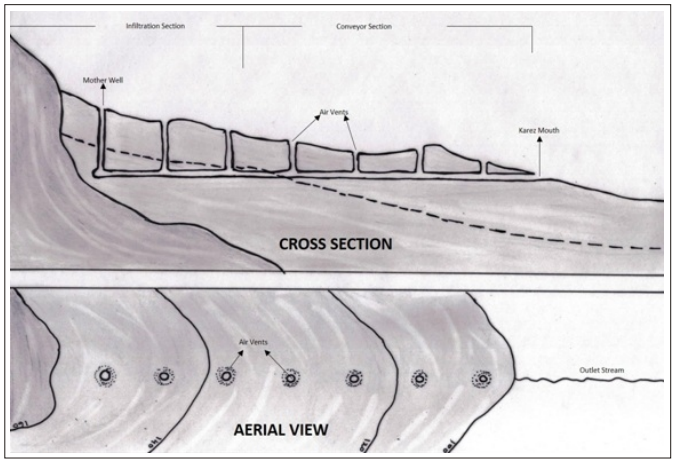


Fig.4: A Cross Section View of Karez

The Bijapur Khair-e-Jari (Fig.5) utilizes both groundwater and surface water. The Khair-e-Jari system includes manmade reservoirs using mud/stone embankments, terracotta pipelines, shallow aqueducts (with lime-mortar-stone masonry work), and a deeper gallery tunnelled through the compact basaltic geology. This is the most complex of all the Karez Systems in India, increasing the value of uniqueness. This also reflects upon the rich knowledge and understanding of the terrain, geology, aquifer system and innovative ingenuity in construction technology. The Bijapur Khair-e-Jari needs to be split into smaller sections, detailed in the following few sections. The Torwi headworks are the catchment of Khair-e-Jari, which includes elaborate arrangements to harvest surface water. The waters from Torwi headworks are carried by a terracotta pipeline to Surang Bawdi (Well) and through the shallow and deep tunnel to the city. A branch tunnel also joins the main system from Ibrahim Talab, enhancing the water supply.

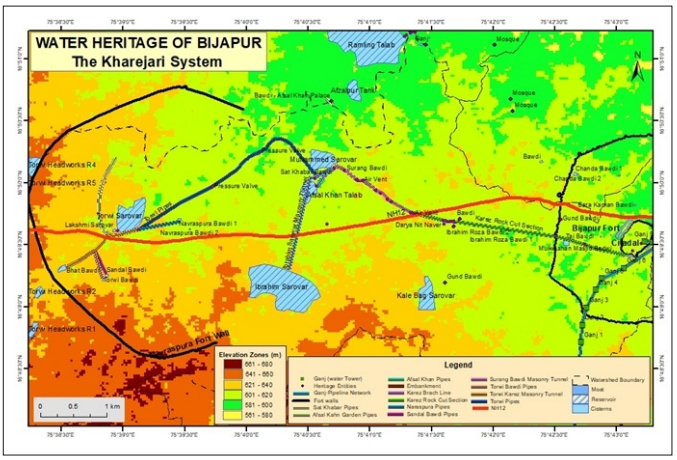


Fig.5: The Khair-e-Jari Water System of Bijapur

The Torwi Headworks

The source of Bijapur Khair-e-Jari is at Torwi / Torwah, about 6 km west of the city. Elaborate catchment arrangements based on the principles of watershed management that have been made to tap both surface water and groundwater. The catchment headworks (Fig.6) include a series of embankments along streams and Bawdi's. The streamflow and surface run-off are diverted to embankments, creating small to big reservoirs. These reservoirs are called *Talab* or *Sarovar*. There are three embankments between the stream source and Bhat Bawdi, the mother well of Khair-e-Jari. An embankment was built across the Torwi stream, forming a small reservoir, ensuring water infiltration and recharging the groundwater table. This ensured that the water level in Mother Well was located alongside the Karez gallery. It reflects that the Karez engineers understood seasonal water fluctuations and addressed them using a simple solution. This is the starting point of Bijapur Khair-e-Jari.

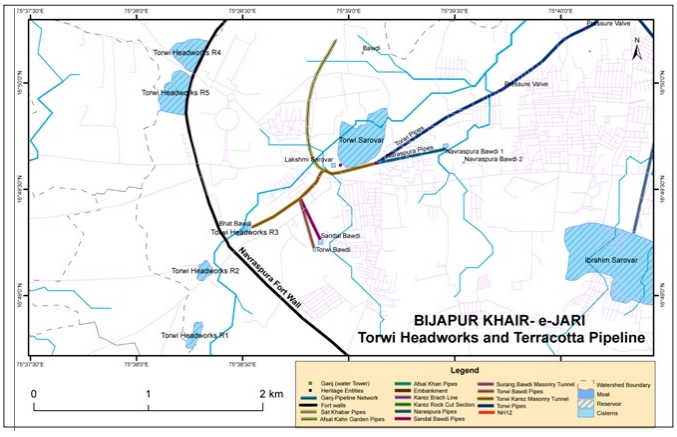


Fig.6: Torwi Headworks and Torwi Terracotta Pipeline

The Torwi tunnels from Bhat Bawdi carry water towards the Lakshmi temple about 800m to the northeast. The tunnel was constructed by open trenching, and the trench was lined with stone

masonry work using lime mortar (Fig.7). The gallery depth is 12ft from the surface, and the height and width of the tunnel are 6ft and 4ft, respectively. Two air vents other than Bhat Bawdi are visible in this section with a dimension of 6 ft x 4 ft. Projected stone slabs have been provided on the walls to climb down into the vent. The parapet of the air vent visible over-ground is 4ft high. The tunnel is dilapidated and cannot be accessed due to debris from collapsed sections and anthropogenic intervention. The third vent is a small Bawdi. The tunnel has been closed using the stone wall at both entry and exit; thus, water movement is restricted. Such anthropogenic interventions can be seen across the Khair-e-Jari landscape.

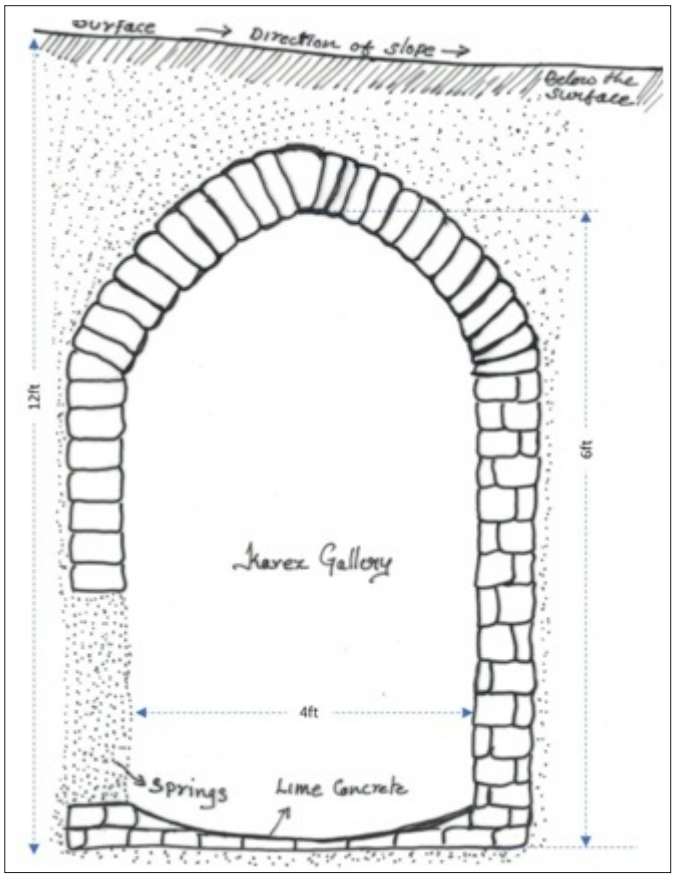


Fig.7: Cross-section of Torwi Tunnel Section of Khair-e-Jari

The *Torwi* tunnel (Fig.7) also receives water from two cisterns, namely *Santhal / Sandal Bawdi* and *Torwi Bawdi,* located 500m east of Bhat Bawdi, using two terracotta pipes of 6-inch diameter. These cisterns have been dug by cutting hard basaltic rock and appropriately lined using stone and lime mortar masonry. They have been decorated with arches as well. These cisterns collect the rainfall water and seepage through the rocks. The dimensions of *Sandal* and *Torwi Bawdi* are 42 x 42 m and 32 x 25m respectively. These huge cisterns with a combined capacity of 48080m^3 (approx.) provided additional support to suffice the water demand.

Another terracotta pipeline from a Bawdi located north of Lakshmi Temple joins Khair-e-Jari (Mate, 1998). The land-use changes in the area have destroyed these pipes completely. An archaeological exploration will be required to unearth the remains of this section. A pipeline joins Khair-e-Jari from Lakshmi Kund (Bawdi) and is located within the temple premises.

The Khair-e-Jari takes a right-angle turn to the East at Lakshmi Temple premises along the Torwi stream and proceeds another 200m towards *Jami Masjid Bawdi* on the right bank. The tunnel ends at this point. This is where the Torwi pipeline starts. On the left bank of Torwi Stream is a reservoir (Torwi Sarovar) created by an embankment constructed to control the floodwaters and divert them to Khair-e-Jari.

The Torwi Terracotta Pipes

The Torwi pipeline is one of the lengthiest terracotta pipelines laid to carry water in India during the medieval period. The pipeline stretches for 3.45 km from Jami Masjid premises to Surang Bawdi. At appropriate intervals, pressure valves with a desilting mechanism (Fig.8) have been created to ensure the smooth flow of water. These exist in two different types: a small 4ft deep pit with inlet and outlet pipes of the same dimension 1ft above the base. This ensures desilting and smooth flow of water, while the second type is a 7ft high structure with a tank (Fig.9). This structure helps maintain the water pressure at the source intact and ensures desilting.

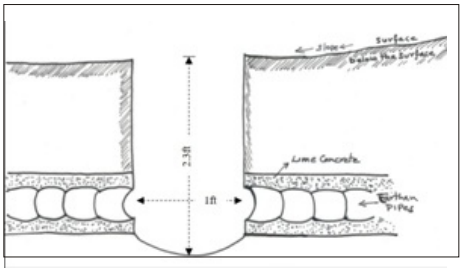


Fig.8: Pressure Valve cum Desilting pit

Fig.9: Pressure Valve cum Desilting tank

Fig.10: Terracotta /Earthen Pipes in Lime Concrete

Interestingly, the Torwi pipelines were constructed to circumnavigate the terrain undulations between Torwi Sarovar and Surang Bawdi. The pipelines (Fig.10) from Jami Masjid run 2.3km towards northeast and make a right angle turn towards southeast, proceeding another km to join other pipelines from Sat Khabar Bawdi and Afsal Khan Sarovar about 100m south of Surang Bawdi (Cousens, 1889; Mate, 1998). All the pipes open up in Surang Bawdi and carry water through a wider yet shallow tunnel towards the city.

The Embankment and Reservoirs

Near Surang Bawdi (Fig.12), three significant embankments create reservoirs: *Mohammed Sarovar*, *Afsal Khan Sarovar* and *Ibrahim Sarovar* (Cousens, 1889; Mate, 1998). All three are on the tributary of the Torwi stream. Muhammed Sarovar with an approx. The capacity of 518,560m^3 is located to the North West of Surang Bawdi, the reservoir spreads towards the South with an area of 8.64 ha. The Torwi Pipes pass under this reservoir. 347m southwest of Surang Bawdi is an Afsal Khan Sarovar embankment with a tall water control structure. Afsal Khan Sarovar has an area of 5.20 ha and an approx. the capacity of 311,780m^3. Still further southwest, about 1.67 km from Surang Bawdi is Ibrahim Sarovar. Ibrahim Sarovar has an area of 47 hectares and an approx. the capacity of 2,827,000m^3. These embankments showcase knowledge and application of watershed management practices. The reservoirs have two purposes: recharging the aquifer, diverting water through pipelines to Khair-e-Jari, and augmenting the water supply to the city. The area of the reservoir cannot be identified as encroachments that have resulted in land-use changes; hence, an estimated area based on a mobile mapping application survey has been used to calculate the volume of water. Urbanization is also fast approaching these sites. Ibrahim Sarovar's embankment is an example of this; urban structures have already come upon it. It also showcases a lack of respect for heritage structures and poor planning and implementation of existing policies for conservation, encouraging unplanned organic urban development.

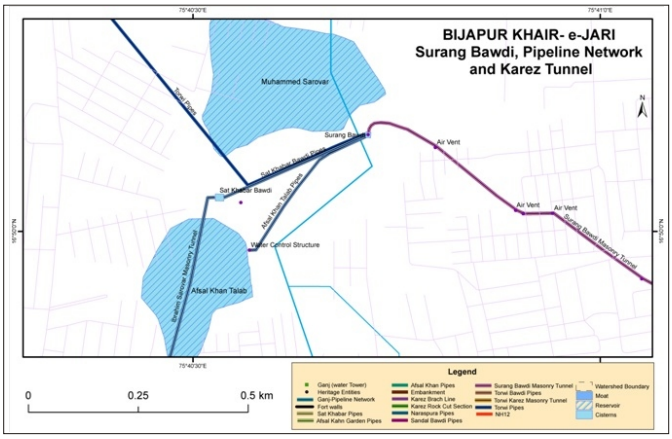


Fig.11: Surang Bawdi, Network of Terracotta Pipelines and Khair-e-Jari Tunnel

A beautifully built water control structure stands on the Afsal Khan Sarovar embankment (Fig.11). The water from Afsal Khan Sarovar is resealed towards Surang Bawdi through pipelines using this control mechanism. Wooden planks have been used as shutters to control the flow of water from the reservoir to pipelines. The Water structure was manned to ensure the timely release of water. There is a small octagonal cistern within the structure.

The Ibrahim Talab to Sat Khabar Bawdi

The Ibrahim Sarovar is connected via a tunnel (1.45km long) to *Sat Khabar Bawdi*. The tunnel is similar to the Torwi tunnel, shallow and lined using stone and lime mortar. The tunnel passes under the *Afsal Khan Sarovar* and empties into *Sat Khabar Bawdi*. The Bawdi has been constructed in the Sat Khabar Complex (60 tombs), and pipelines from this Bawdi lead to *Surang Bawdi*. The tunnel is dilapidated, with many sections collapsed. Few of the air vents are still visible, but land conversion from agriculture to urban has resulted in the filling up of collapsed sections and air vents. The *Sat Khabar bawdi* is brought into use by the local farming community during summer for irrigation. Most open wells dry during summer, but the Sat Khabad Bawdi continues to have water till late summer. The collapse of sections of bawdi has resulted in silting and thus reduced capacity. Terracotta pipelines from Towri, *Sat Khabar Bawdi* and *Afsal Khan Sarovar* culminate at *Surang Bawdi,* located 365m Northeast of *Afsal Khan Sarovar* embankment.

Fig.12: Water Control Structure at Afsal Khan Sarovar

The Surang Bawdi

Surang Bawdi is the culmination point of all the pipelines. It's a near square well; on the southwest side, pipelines from Sat Khabar Bawdi, Afsal Khan Sarovar, and Torwi can be seen, while on the north side, the tunnel towards the city starts. The Bawdi is 12m sq. with a depth of 20ft. The base of the tunnel is 14ft. The Bawdi was completed and filled with debris as part of the land recovery process to convert it into non-agricultural land use. Intervention by the Archaeological Survey of India and local heritage activists led to its excavation. But the work was abandoned in between and is now lying in dilapidated condition with stagnant water.

The Surang-Bawdi to Sainik School Khair-e-Jari Section

The Tunnels run in a northeasterly direction for about a few meters and swing south-easterly towards the present-day Sainik school campus. The tunnel is 12ft wide and 7ft high, lined with stone and lime mortar. Approximately 3ft of space along the length of the tunnel from its foundation has been left unlined to allow subsurface water to flow into the tunnel. The tunnel has been constructed by open trenching and further covering it using stone masonry with lime mortar (Fig.13). Air vents or manholes in this section could be located at every 20m interval. Most others have disappeared due to urbanization. This section is also the most polluted, with sewerage leaking into the tunnel. Further, the tunnel depth suddenly changes from 14ft to 87ft (at the nearest accessible point). The exact location of a sudden change in height has not been located in this section due to pollution and debris. The deeper section of the tunnel starts near the Sainik school campus and proceeds towards *Ibrahim Roza* (tomb of Ibrahim Adil Shah II) via *Darya-nit-Naver* (Dargah) (Cousens, 1889).

The basalt layers of the Deccan Trap have been cut and tunnelled; the depth varies from 60 to 90ft. Most of the air vents in this section have been closed, but few are still visible over the surface. Air vents had a dome-shaped masonry structure made of basalt stone and lime mortar to protect the water from pollution. Urban development and land-use change have negatively impacted the air vents; most have been destroyed, and those remaining are dilapidated.

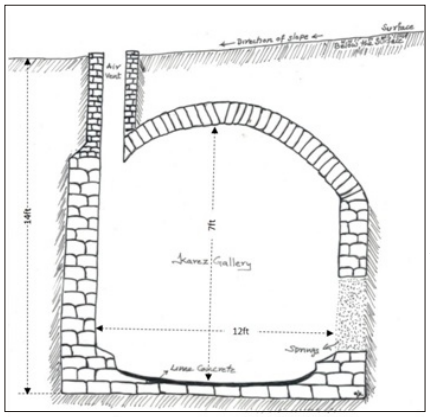


Fig.13: Karez Tunnel Cross Section (Surang Bawdi-Sainik School

The Sainik School to Mecca Gate Kahr-e-jari Rock Cut Tunnel Section

At *Darya-nit-Naver*, water structures point to lifting water to fill the cistern. This is the first supply point of Khair-e-Jarifurther, the tunnel proceeds toward *Ibrahim Roza*. The tunnel is 2 to 3ft wide, and the width varies due to the rough cutting of basalt stone (Fig.14). The air vents can be detected up to *Ibrahim Roza*; thereafter, the tunnel's direction cannot be traced from the surface.

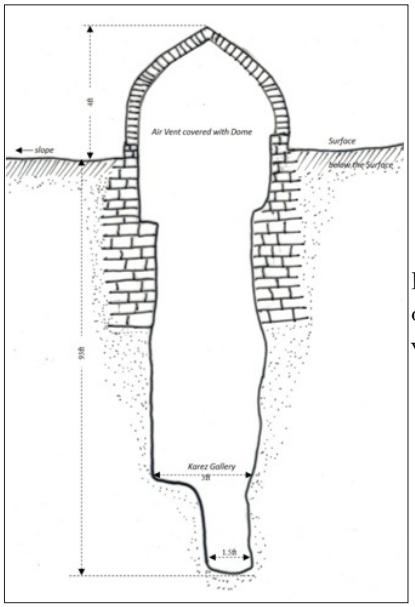


Fig.14: Rock-cut Section of Khair-e-Jari Tunnel with dome-covered vent

The tunnel passes under *Ibrahim Roza*, enters the walled city alongside Makka gate and branches off in different directions. One branch proceeds north of Taj Bawdi and alongside Jod Gumbaz and Khawas Khan Palace, Khawas Khan Tomb and terminates at the inner moat (Nazim, 1836; Cousens, 1889). Another branch moves towards the unfinished tomb of Ali II and Fath Khan Palace (Nazim, 1836). At *Ibrahim, Roza* water is lifted from Khair-e-Jari to fill two cisterns. The Khair-e-Jari fills the Bawdi enroute, and a pipeline connects it to Taj Bawdi (Nazim, 1836; Cousens, 1889), but very recently, it was cleaned, and no pipe inlets could be found. The emptying of Taj Bawdi revealed the fractured and weathered basaltic geology, which ensured a good flow of water. Groundwater springs are flowing into the Bawdi. Henry Cousens (1889) mentions the tunnel ends near a temple alongside the inner moat.

The Khair-e-Jari formed a unique water supply system of Bijapur during the 16th to 18th century AD. These are unique water systems compared to Persian Qanats, which operate purely on groundwater or subsurface snowmelt water, with most running through near desertic conditions. While the Bijapur karez is one of the best examples of watershed management practices. The water system was abandoned with the arrival of modern technology to extract water, as well as the rapid unplanned organic growth of the city. Like most historic structures, Khair-e-Jari doesn't figure in the priority list of conservation. Thus, it is abandoned in a dilapidated condition, with sections disappearing daily under new land-use change due to urbanization.

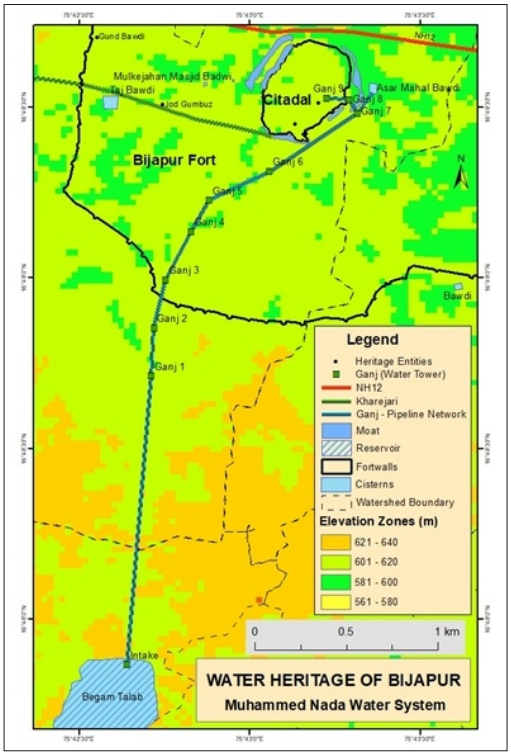


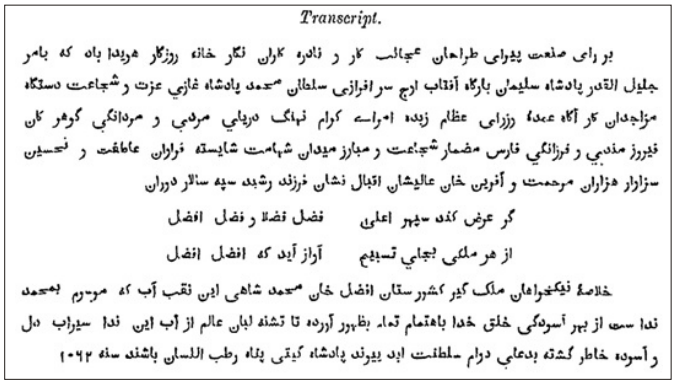
Fig.15: The Muhammed Nada Water System of Bijapur

Muhammed Nada' – The Unique Pipeline Urban Water System

Yet another unique urban water system that ensured the availability of potable water to citizens of Bijapur is *'Muhammed Nada'* (Nazim, 1936). *'Muhammed Nada' is* a unique network of pipelines, Ganj (overhead tank) and cisterns originating from *Jahan Begum Talab* to *Asar Mahal (built by Mohammed Adil Shah in about 1646 to serve as the Hall of Justice)*. No other place has ever documented such a unique water supply system. This historic urban water supply network was named *'Muhammed Nada"* (Nazim, 1836) (Fig.15).

This is not a Karez system, but it is worthy of mentioning here as it is probably the first of its kind 24x7 urban pipeline water supply system. This water system was initiated during the period of Muhammed Adil Shah under the supervision of Afsal Khan. The

water system was called '*Muhammed Nada*' (inscription at water tower near Andu Masjid) and was completed in the year 1662AD (Nazim, 1936).


Transcript.

بر رای صنعت پیرای طراحان عجائب کار و نادره کاران نگار خانه روزگار هرویدا باد که بامر جلیل القدر پادشاه سلیمان بارگاه آفتاب اوج سر افرازی سلطان محمد پادشاه غازي عزت و شجاعت دستگاه مزاجدان کار آگاه عمدهٔ وزرای عظام زبده امرای کرام نهاک دریاي مردي و مردانگي گوهر کان فیروز مندي و فرزانگي فارس مضمار شجاعت و مبارز میدان شهامت شایسته فرازان عاطفت و تحسین سزاوار هزاران مرحمت و آفرین خان عالیشان اقبال نشان فرزند رشید سپه سالار دوران

گر عرض کند سپهر اعلی فضل فضلا و فضل افضل
از هر ملکی بجاي تسبیحم آواز آید که افضل افضل

خلاصهٔ نیکخواهان ملک گیر کشور ستان افضل خان محمد شاهی این نقب آب که موسوم بمحمد ندا ست از بهر آسودگی خلق خدا باتمام تمام بظهور آورده تا تشنه لبان عالم از آب این ندا سیراب دل و آسوده خاطر گشته بدعاي دوام سلطنت ابد پیوند پادشاه گیتی پناه رطب اللسان باشند سنه ۱۰۷۲

"Be its manifest to the art-decorating intellect of the wonder-working architects and the exquisite artisans of the picture-gallery of the world that at the command of exalted dignity of Padshah, with a count like that of Solomon, sun of the zenith of eminence, Sultan Muhammad Padshah the Ghazi (possessor of) the capital of bravery and honour, sagacious confidant, pillar of the great Wazirs, select of eminent Amirs, alligator of the sea pf courage and bravery, diamond of the mine of victory and sagacity, rider in the battle-field of intrepidity and warrior in the plain of bravery, deserving of plenty of graces and applauses, entitled to thousands of clemencies and approbations, the Khan of high rank, having the stamp of prosperity, well-guided son, commander of the army of the period, If the exalted heaven were to display for comparison, the excellence (fazl) of the excellent persons and the excellence of Afzal, Instead of the Tasbish (repetition of Allah's praise), every angel, shall recite, "Afzal is Excellent" (Nazim, 1936).

The quintessence of well-wishers, kingdom-takers, and conquerors of countries, Afzal Khan-i-Muhammed Shahi brought into existence with excellent management, this conduit, known as Muhammad-Nada (meaning Muhammad's Moisture) for the comfort of the creation of God, so that the thirsty-lipped of the world, having comforted and refreshed their hearts by the water of this conduit, may keep their tongue moist with prayers for the permanence of the kingdom, which is linked with eternity, of Padshah who is the asylum of the world. The year 1062 (1662A.D.)". (Nazim, 1936).

The source of this water system is Jahan Begum Talab, an artificial reservoir. Begum Talab was constructed in 1665 during the period of Muhammed Adil Shah to augment the water supply in Bijapur city. The talab is located at a comparatively higher altitude than the city, with an area of 1.02 sq km. As an intake system, a basalt stone masonry structure lined with lime mortar was constructed on the northern part of Begum Talab. Pipes with a diameter of 16 inches were laid at about 15 feet deep to carry water. To ensure that the pipes maintain the right pressure and supply water to citizens, about 245m apart stone masonry towers with varying heights of 25 to 40ft based on location were erected; such structures are called Ganj. Every Ganj has a tank above it, with one inlet pipe and many smaller outlet pipes. Each outlet pipe leads to a cistern, palace, or garden. The people had access to water 24/7 through public cisterns.

Some of these Ganj have been destroyed due to urbanization, and some still exist in an abandoned state and can be seen within the walled city. One ofthe largest Ganj can be located at Mecca Masjid (Fig.16). This Ganj is 40ft tall with a tank dimension of 5.5 m x 5.5 m x 2.5 m and an approximate capacity of 75.625m^3. The tank has two inlet pipes and many outlet pipes; the pipe sizes vary; those with a 2-inch diameter go to individual households or cisterns, and those with a 6-inch diameter are main inlet pipes bringing water from Begum Talab and exit pipes carrying water to next Ganj. A pipeline from Ganj leads to Bawdi at Asar Mahal. Most of the Ganj is in an unprotected state on private property. Limited measures have been taken to restore or protect them from vandalism.

Fig.16: Ganj / Water Tower near Mecca Masjid

Network of Bawdi's

Besides these two urban water systems bringing water to the city, many Bawdi's / Baori (Cisterns) are constructed to store water. These have been built as an alternative to the other two systems. In a war or siege, the enemy likely blocked or polluted both Karez and the pipeline network from Begam Talab. Hence, Bawdis dot the fortified city. The prominent Bawdi include Taj Bawdi, the largest one (233ft Sq.), Chand Bawdi near Shahpur Gate, Bari Bawdi and Mubarak Khan's Bawdi in SE, Masa and Nim Bawdi in the North East, Hilal and Nagar Bawdi, and the Jami Masjid Bawdi in the south. The other Bawdi'ss include Badi Bawdi, Bibi Bandi Bawdi, Gumat Bawdi, Chini Mahal Bawdi, Mustafa Khan Bawdi, Ilal Bawdi, Hdilas Khan Mosque Bawdi, Rafia Bawdi, Khwas Khan palace Bawdi and Padshah Bawdi (Nazim, 1836; Cousens, 1889; Mate, 1998). The size and capacity of these Bawdi's vary.

The spatial distribution of Bawdi's is one of the most ideal in the case of Bijapur, catering for every part of the fortified area and community. Some of these Bawdi's were connected to the Ganj by pipelines. Hence, constant replenishment of water happened. The Bawdi's also have a manual water lifting system for irrigation and household-level supply. These Bawdi's are still being used for domestic chores and irrigation. The local community finds various uses for the Bawdi, especially for washing clothes. Bawdi's located outside the fort complex are used for irrigation, as they often retain water even during the harsh summer. Some Bawdi's within the fort enclosure serve as recreational spots for children.

Similar to the Khair-e-Jari and Ganj, Bawdi's are also in dilapidated condition; few of them have been protected physically, but the water is highly polluted, stinky and poses a health hazard to people. The people of the neighbourhood even use these cisterns for washing clothes. The Taj Bawdi was cleaned and removed from all the debris in 2015, but with a lack of awareness, maintaining it clean is a challenge in itself.

Discussion

When it comes to historic urban water systems, the most prominent ones are the overground Roman aqueducts at Rome or Port du Gard in France and the Persian Qanat systems serving cities like Yazd or Esfahan have been provisioned for many other purposes as well, like running floor mill, windcatchers (Badgir) or cooling towers etc. Similarly, the Indian Karez systems are unique, including the use of multiple sources, pipelines, pressure-controlling mechanisms, and the indigenous 'Mohammed Nada' water system. These increase the value and character of Bijapur's urban heritage.

Though the Government of Karnataka and the Archaeological Survey of India's proposal in 2014 has resulted in Monuments and Forts of the Deccan Sultanate being included in the UNESCO World Heritage Site tentative list *(https://whc.unesco.org/en/tentativelists/5887/)*, there isn't any process toward integration of heritage conservation and the urban planning process. There are sufficient laws like Karnataka Town and Country Planning Act 1961, Karnataka Land Revenue Act 192A- Section 95CA, Karnataka Municipal Act, Bijapur Municipal Bye-Laws, Karnataka State Ancient Monuments Archaeological Sites and Remains Act 1961, and the Environmental Protection Act 1986, to accorded protection as the first step towards conservation, but least implemented beyond certain prominent structures that earn revenue from tourists.

The city municipal body cannot efficiently cater to all the sectors when it struggles to provide basic amenities to the population of 3.27 lakh (0.327million) (Census of India, 2011). With a density of 265 persons/km^2 (Census of India, 2011), the city faces a massive challenge in choosing from heritage and providing better infrastructure, sanitation, housing for the poor, etc. Under such circumstances, the way forward is to integrate conservation plans with the city master plan and provide initial protection to the water heritage of Bijapur, like the Khair-e-Jari, Bawdi and Muhammed Nada water systems. Physical conservation can happen only when the community of Bijapur realizes the significance of such heritage structures through appropriate use.

The drought-prone city of Bijapur faces an acute shortage of water during the summer season (Venkatesh & Vijaysree, 2009; CGWB, 2008). The city's centralized water supply system is stretched to its limits during summer. If maintained and protected appropriately, heritage structures like Bawdi, Muhammed Nada, and Khair-e-Jari can be sources of decentralized water systems that help the community move towards sustainability. It is for sure that these heritage systems won't suffice the demand, but they can be a stress reliever to the centralized system. The Bawdi's and Khair-e-Jari can also be used as groundwater recharge structures to ensure water storage in the vesicular basaltic aquifer. This can grow into a win-win situation for both heritage and the community of Bijapur.

Thus, the community needs to feel pride in its heritage and own it, and then implementing the existing laws can provide sufficient teeth for protection and conservation efforts. The heritage of a city is a community resource if put to appropriate use.

Conclusion

The significance of Bijapur's historic water system extends far beyond its historical value. It offers a wealth of knowledge and inspiration for creating more sustainable and resilient cities. By actively researching, restoring, and learning from this remarkable system, we can ensure its preservation for future generations while reaping its many benefits for the present. Further, research and collaboration with various stakeholders including archaeologists, geographers, hydrogeologists, engineers, urban planners and the local community to unlock the current challenges and undertake an integrated and interdisciplinary approach to the protection and sustainability of urban water heritage. Bijapur's water system exemplifies a remarkable understanding of watershed-based urban planning and land use management practices during medieval times. This knowledge, coupled with modern technology like GIS, can aid in heritage preservation and inform the development of integrated master plans for contemporary cities. The system's diverse components demonstrate effective integrated water management principles, from the Khair-e-Jari tapping into groundwater to the Bawdi's storing rainwater. This approach can inspire modern urban water systems to become more diverse and resilient. Bijapur's historic water system demonstrates the feasibility of creating a sustainable and self-sufficient urban environment. By studying its design and operation, we can learn valuable lessons for creating modern cities that are less reliant on external resources and more environmentally friendly.

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